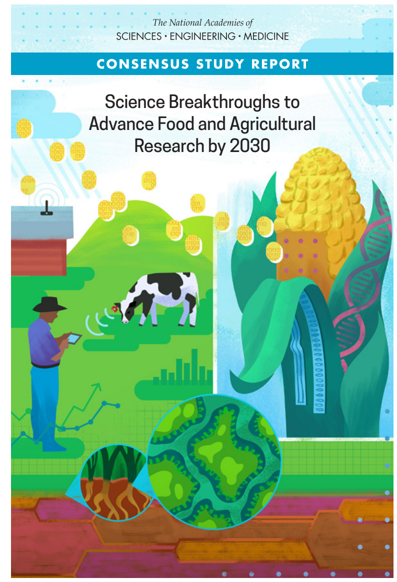
Consensus Study Report

HIGHLIGHTS

July 2018

Science Breakthroughs to Advance Food and Agricultural Research by 2030



For nearly a century, scientific advances have fueled progress in U.S. agriculture to enable American producers to deliver safe and abundant food domestically while also generating a trade surplus in bulk and high-value agricultural commodities and foods. Recent analyses indicate that agricultural production worldwide will have difficulty keeping up with food demands of the world's growing population. Sustainably achieving a higher level of productivity will require: (1) new approaches for leveraging capabilities across the scientific and technological enterprise; (2) breakthroughs that could dramatically increase the capabilities of food and agricultural science; and (3) increased investments in the tools, equipment, facilities, and human capital to conduct cutting-edge research in food and agriculture.

The United States has been the world's leading agricultural producer for many years, but the U.S. food and agriculture system will be tested as world food production must increase significantly to meet the needs of a global population expected to reach 8.6 billion by 2030. In addition, natural systems are stressed by water scarcity and regional impacts in a changing climate, such as increased weather variability, floods, and droughts.

On its current path, increased U.S. agricultural production is likely to come with tradeoffs. For some crops, such as soybeans, it may be no longer possible to continue increasing yields and nutritional value without sacrificing water quality and soil resources and the surrounding ecosystem. Increased food animal production is generating more greenhouse gas emissions and excess animal waste. Currently, about a third of the food produced in the United States is wasted, primarily at the retail and consumer stages. There is a need to find new methods, processes, and systems to better handle and preserve food supply.

In the next decade, stresses on the U.S. food and agricultural enterprise are unlikely to be resolved if business as usual prevails. This report identifies innovative scientific advances for making the U.S. food and agricultural system more efficient, resilient, and sustainable. The report's authoring committee identified the most promising scientific breakthroughs that could have the greatest positive impact on food and agriculture, and that are possible to achieve by 2030.

MAJOR GOALS AND KEY CHALLENGE AREAS

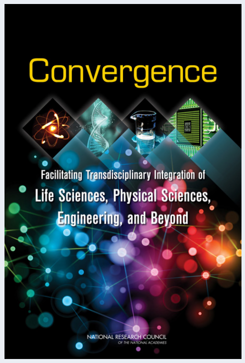
The committee held discussions with members of the scientific community to identify the most challenging issues facing food and agriculture and the best opportunities for research to address them. In the next decade, the major goals for food and agricultural research include: (1) improving the efficiency of food and agricultural systems; (2) increasing the sustainability of agriculture; and (3) increasing the resiliency of agricultural systems to adapt to rapid changes and extreme conditions. Those goals derive from key research challenges identified by the community, which include the following:

- increasing nutrient use efficiency in crop production systems;
- reducing soil loss and degradation;
- mobilizing genetic diversity for crop improvement;
- optimizing water use in agriculture;
- improving food animal genetics;
- developing precision livestock production systems;
- early and rapid detecting and prevention of plant and animal diseases;
- early and rapid detection of foodborne pathogens; and
- reducing food loss and waste throughout the supply chain.

CONVERGENCE: A NEW APPROACH TO AGRICULTURAL RESEARCH

In the past, it has been common to examine problems within a defined discipline for reasons related to practicality and greater ease of management. This approach has been effective at addressing distinct issues that require knowledge in a specific domain. However, the urgent progress needed today requires leveraging capabilities across the scientific and technological enterprise in a convergent research approach (Box 1).

Food and agricultural research needs to be broadened to harness advances in data science, materials science, and information technology. Furthermore, integrating the social sciences (such as behavioral and economic sciences) to correctly frame problems and their solution space is essential, as the food and agricultural system is as much a human system as a biophysical one.



Box 1.

The 2014 National Research Council report *Convergence: Facilitating Transdisciplinary Integration of Life Sciences* describes convergence as “an approach to problem solving that cuts across disciplinary boundaries [and] integrates knowledge, tools, and ways of thinking from life and health sciences, physical, mathematical, and computational sciences, engineering disciplines, and beyond to form a comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields.”

SCIENCE BREAKTHROUGHS: NEW TOOLS FOR TACKLING AGRICULTURAL RESEARCH

The committee identified five breakthrough opportunities that could dramatically increase the capabilities of food and agricultural science, and recommended building significant research efforts around them.

1. Transdisciplinary science and systems approaches should be prioritized to solve agriculture’s most vexing problems.

A systems approach to understand the nature of interactions among the different elements of the food and agricultural system can be leveraged to increase overall system efficiency, resilience, and sustainability. Such progress can occur only when the scientific community begins to more methodically integrate science, technology, human behavior, economics, and policy into biophysical and empirical models. For example, there is the need to integrate the rate and determinants of adopting new technologies, practices, products, and processing innovations into food and agricultural system models. This approach is required to properly quantify projected shifts in resource use, market effects, and response, and to determine benefits that are achievable. Consideration of these system interactions is critical for finding holistic solutions to the food and agricultural challenges that threaten our security and competitiveness.

2. Create an initiative to more effectively employ existing sensing technologies and to develop new sensing technologies across all areas of food and agriculture.

The development and validation of precise, accurate, field-deployable sensors and biosensors will enable rapid detection and monitoring capabilities across various food and agricultural disciplines. Scientific and technological advances in materials science, microelectronics, and nanotechnology are now poised to create novel nanosensors and biosensors to continuously monitor an array of environmental conditions and stressors. For example, in situ soil and crop sensors could provide continuous data feed and alert the farmer when moisture content in soil and turgor pressure in plants falls below a critical level, and initiate site-specific irrigation to a group of plants, eliminating the need to irrigate the entire field. *In planta* sensors could quantify biochemical changes in plants caused by an insect pest or a pathogen, alerting and enabling the producer to plan and deploy immediate site-specific control strategies before the infestation occurs or the damage is visible. Biosensors for food products could indicate product spoilage and alert distributor and consumers to take necessary action.

3. Establish initiatives to nurture the emerging area of agri-food informatics and to facilitate the adoption and development of information technology, data science, and artificial intelligence in food and agricultural research.

The application and integration of data sciences, software tools, and systems models will enable advanced analytics for managing the food and agricultural system. The food and agricultural system collects an enormous amount of data, but has not had the right tools to use it effectively. Data generated in research laboratories and in the field have been maintained in an unconnected manner, preventing the ability to generate insights from its integration. The ability to more quickly collect, analyze, store, share, and integrate highly heterogeneous datasets will create opportunities to vastly improve our understanding of the complex problems, and ultimately, to the widespread use of near-real-time, data-driven management approaches.

4. Establish an initiative to exploit the use of genomics and precision breeding to genetically improven traits of agriculturally important organisms.

The ability to carry out routine gene editing of agriculturally important organisms will allow for precise and rapid improvement of traits important for productivity and quality. Gene editing—aided by recent advances in genomics, transcriptomics, proteomics, and metabolomics—is poised to accelerate breeding to generate traits in plants, microbes, and animals that improve efficiency, resilience, and sustainability. Comparing hundreds of genotypes using omics technologies can speed the selection of alleles to enhance productivity, disease or drought resistance, nutritional value, and palatability. For instance, the tomato metabolome was effectively modified for enhanced taste, nutritional value, and disease resistance, and the swine genome was effectively targeted with the successful introduction of resistance to porcine reproductive and respiratory syndrome virus. This capability opens the door to domesticating new crops and soil microbes, developing disease-resistant livestock, controlling organisms' response to stress, and mining biodiversity for useful genes.

5. Establish an initiative to increase the understanding of the animal, soil, and plant microbiomes and their broader applications across the food system.

Understanding the relevance of the microbiome to agriculture and harnessing this knowledge to improve crop production, transform feed efficiency, and increase resilience to stress and disease. Emerging accounts of research on the human microbiome provide tantalizing reports of the effect of resident microbes on our body's health. In comparison, a detailed understanding of the microbiomes in agriculture—animals, plants, and soil—is markedly more rudimentary, even as their functional and critical roles have been recognized for each at a fundamental level. A better understanding of molecular-level interactions between the soil, plant, and animal microbiomes could revolutionize agriculture by improving soil structure, increasing feed efficiency and nutrient availability, and boosting resilience to stress and disease. With increasingly sophisticated tools to probe agricultural microbiomes, the next decade of research promises to bring increasing clarity to their role in agricultural productivity and resiliency.

FURTHER CONSIDERATIONS

The science breakthroughs alone cannot transform food and agricultural research, as there are other factors that contribute to the success of food and agricultural research. Such factors include the research infrastructure, funding, and the scientific workforce.

Conclusion 1: Investments are needed for tools, equipment, facilities, and human capital to conduct cutting-edge research in food and agriculture. Addressing agriculture's most vexing problems in a coherent manner will require investments in research infrastructure that facilitate convergence of disciplines on food and agricultural research. These could include physical infrastructure for experimentation as well as cyber infrastructure that enable sharing of ideas, data, models, and knowledge.

Conclusion 2: The Agricultural Experiment Station Network and the Cooperative Extension System deserve continued support because they are vital for basic and applied research and are needed to effectively translate research to achieve impactful results in the food and agricultural sectors. The agricultural sciences are grounded in the basic sciences but have an eye toward the applied; this has historically been facilitated by state agricultural experiment stations, as well as by extension and outreach efforts. Personnel and facilities with these functions allow scientists to translate laboratory-based findings into real-world products and processes that are most relevant, ultimately reaching key stakeholders including industry, regulatory agencies, farmers and ranchers, and the general public.

Conclusion 3: Current public and private funding for food and agricultural research is inadequate to address critical breakthrough areas over the next decade. If a robust food system is critical for securing the nation's health and well-being, then funding in both the public and private sectors ought to reflect this as a priority. In the past decade, the United States has lost its status as the top global performer of public agricultural R&D. Unless the United States reverses this trend and invests, the United States will fall behind other countries in terms of agricultural growth.

Conclusion 4: Efforts to renew interest in food and agriculture will need to be taken to engage non-agricultural professionals and to excite the next generation of students. Vast opportunities are available for non-traditional agricultural professionals to be involved in food and agriculture. A robust workforce for food and agricultural research will require talented individuals who are proficient in the challenges facing the food system along with an understanding of the opportunities to think outside the box for innovative approaches.

Conclusion 5: A better understanding of linkages between biophysical sciences and socioeconomic sciences is needed to support more effective policy design, producer adoption, and consumer acceptance of innovation in the food and agricultural sectors.

Better understanding of the political economy, behavioral and choice processes related both to adoption and use of the technological innovation, and acceptance and perception of new products will be required to support the effective design of policies and application of the research innovation. Lessons from behavioral sciences may help support behavioral change and training requirements.

COMMITTEE ON SCIENCE BREAKTHROUGHS 2030: A STRATEGY FOR FOOD AND AGRICULTURAL RESEARCH

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